FUN WITH CHEMISTRY

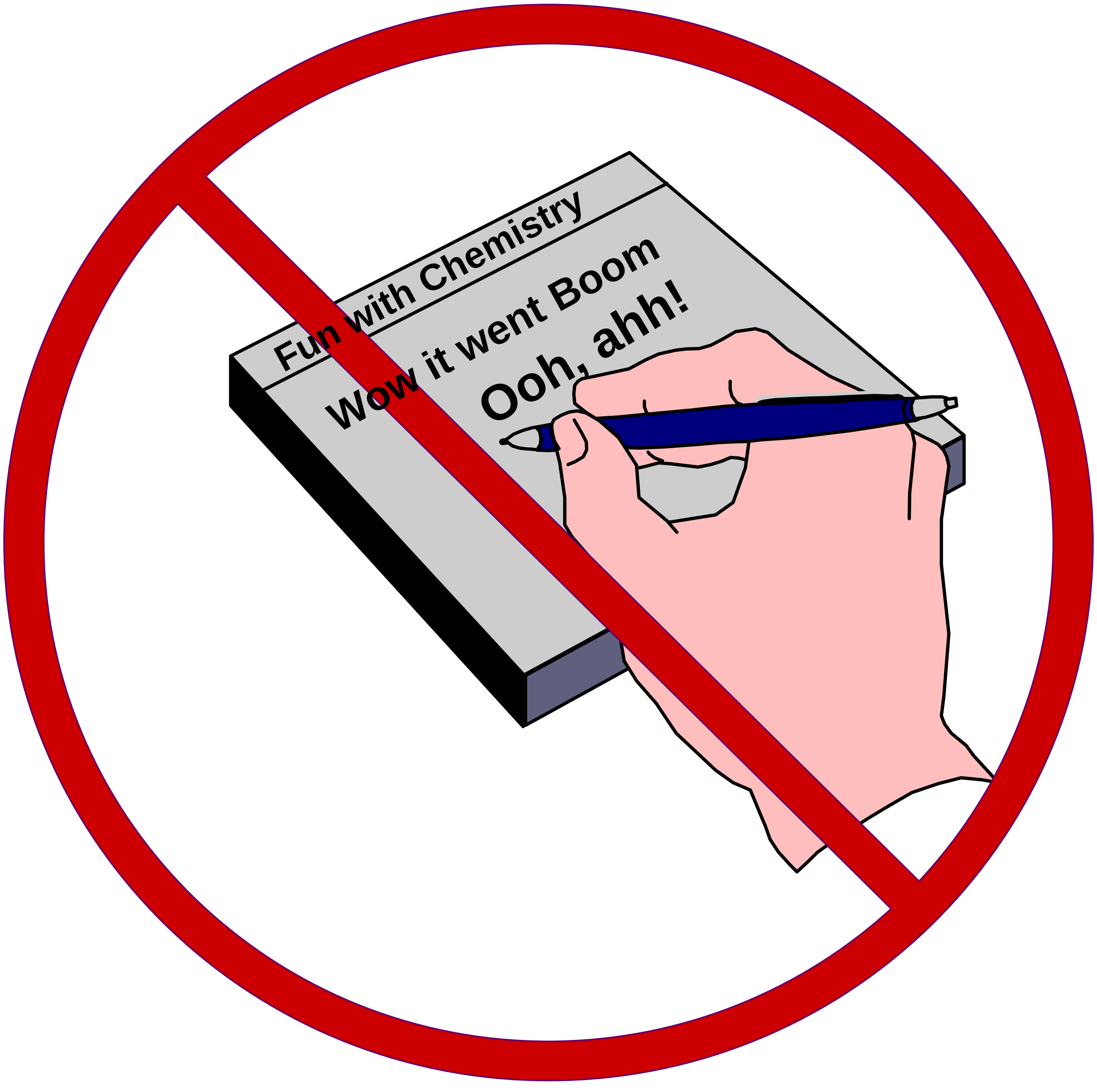
Safety Statement

- The demonstrations performed today involve chemicals in active chemical reactions. They have all been developed, tested and published by professionals in the Chemistry Education Field. We have performed them repeatedly without incident though we want to mention that outcomes can be unpredictable.
- If you have pre-existing respiratory conditions, known allergic reactions to chemicals, are sensitive to loud noises, or if you are simply concerned, you may consider sitting near the rear of the classroom, closer to the outdoor ventilation
- This seminar is offered as information only. No warranty, representation, or guarantee is made by the instructors as to the accuracy or sufficiency of the information offered during this seminar. Any references to laws and regulations must be verified in appropriate legal reference sources before use out in the field.
- Do not attempt any of these demonstrations on your own based on information gathered during this seminar. There must be extensive education, research, testing, and practice done before attempting to perform any of these demonstrations.
- Per Proposition 65, note that some of the flammable and combustible liquids used today are known by the State of California to cause cancer, birth defects or other reproductive harm.

FUN WITH CHEMISTRY

Dan Keenan

Maria Duazo



Fun with Chemistry
Wow it went Boom
Ooh, ahh!

"Good judgement proceeds from clear understanding,

clear understanding comes from reason derived from sound rules,

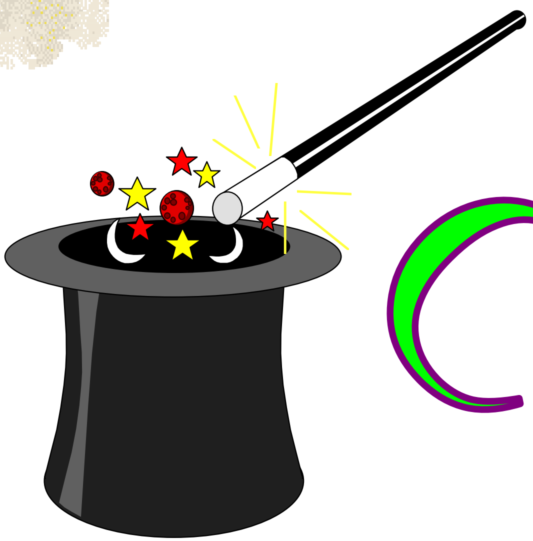
and sound rules are the daughters of

Two Types of Change:

Physical

&

Chemical



Explosions

- Many types:

nuclear : fission (splitting atomic nuclei)

fusion (smashing H to make He)

chemical: detonation (high explosives)

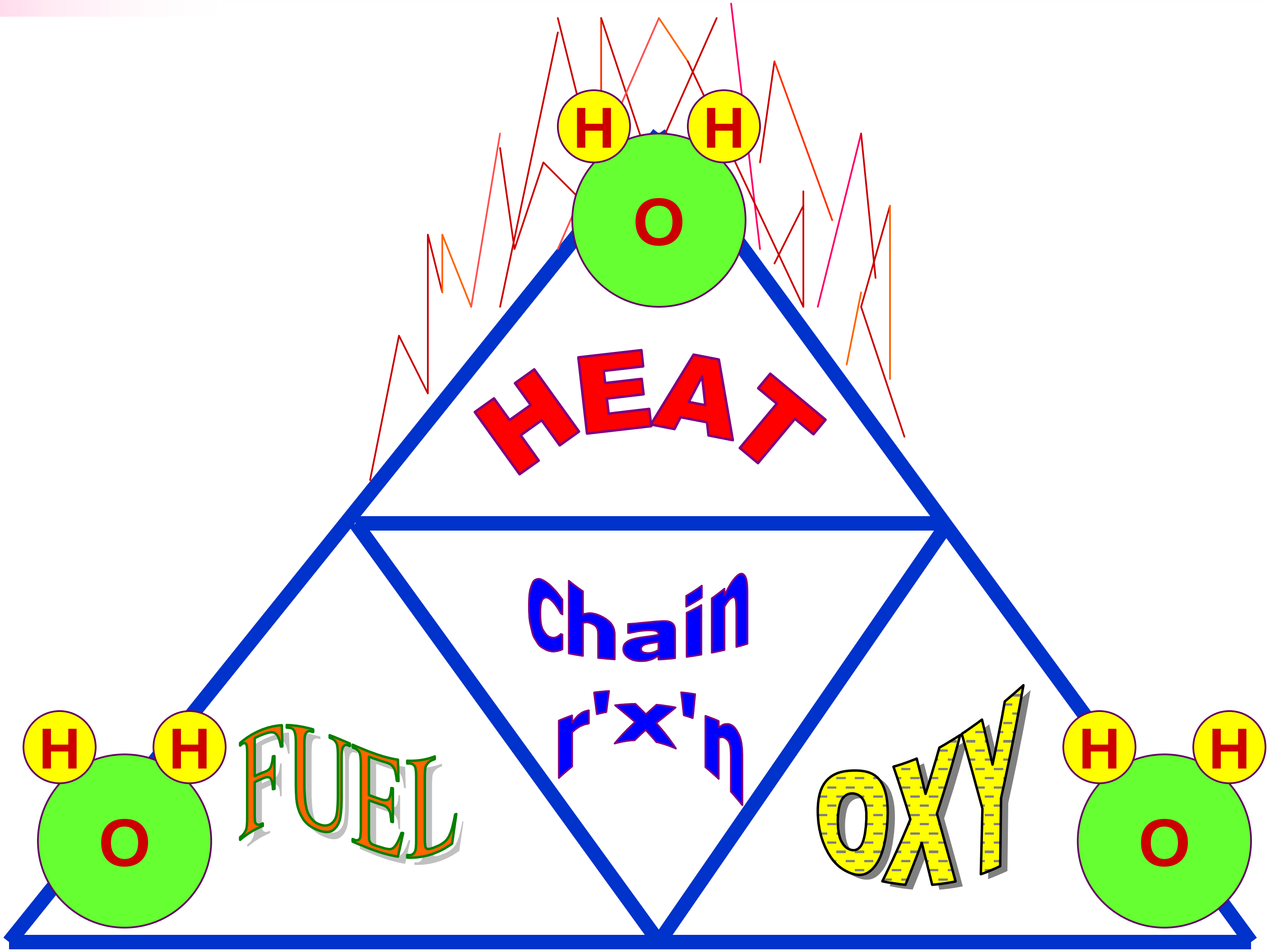
deflagration (low explosives)

<u>mechanical</u> pressurized container failure

Caused by a *physical change*


B.L.E.V.E


implosion

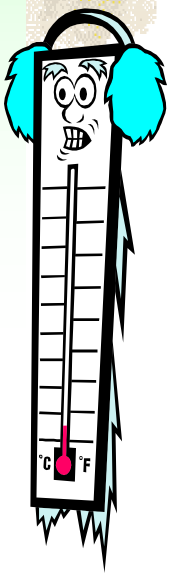

HEAT
Chain r'x'n
FUEL
OXY
H
H
O
H
H
O
H
H
O

Cryogenics

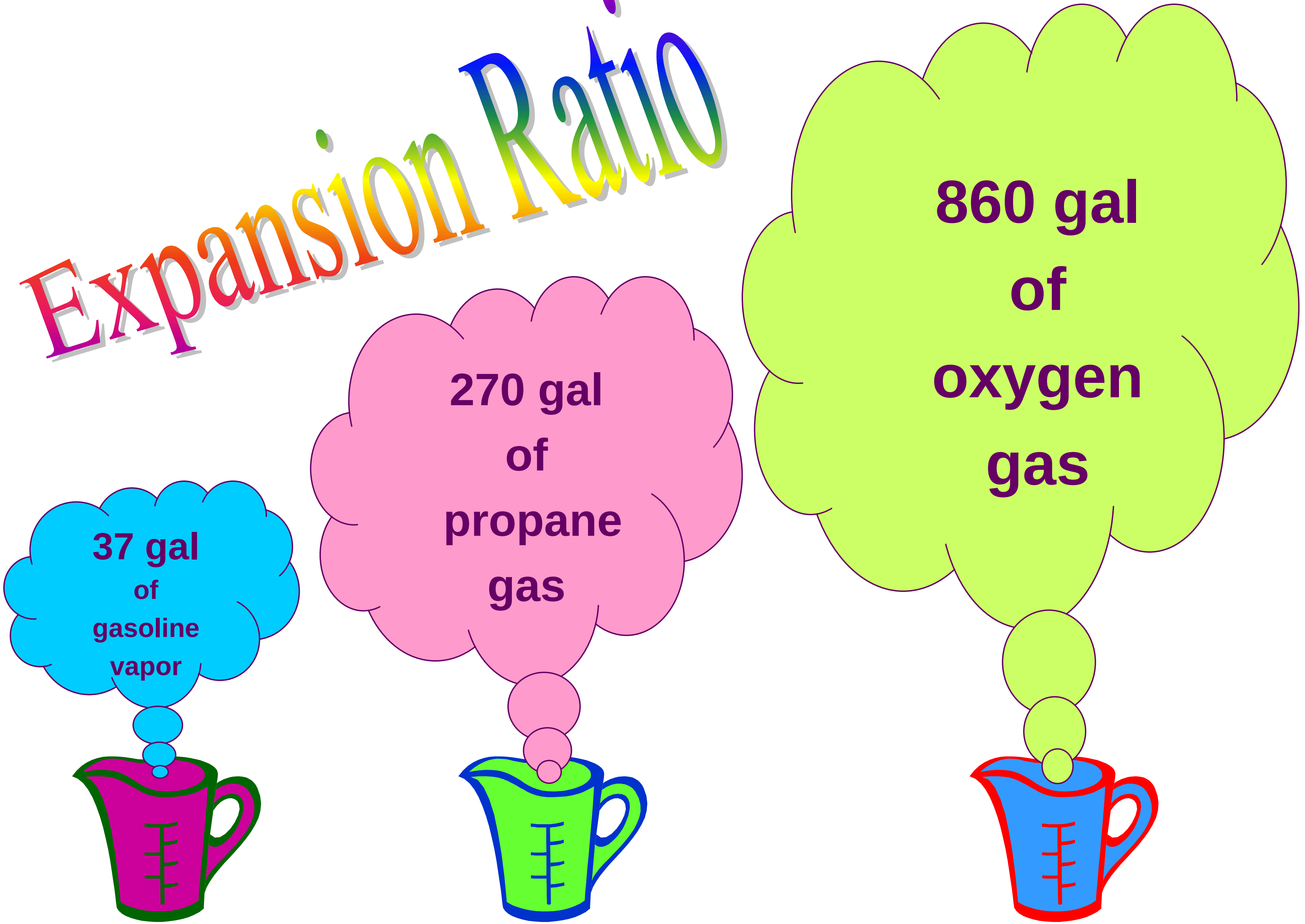
- ***Liquefied Refrigerated gases with boiling points less than*** *-130°F*

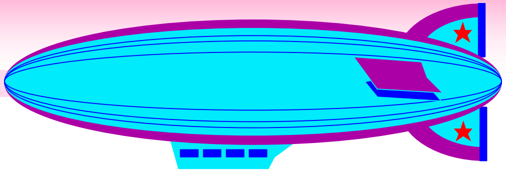
Helium *-452°F* ***Nitrogen*** *-321°F*

Oxygen *-291°F* ***Hydrogen*** *-423°F*



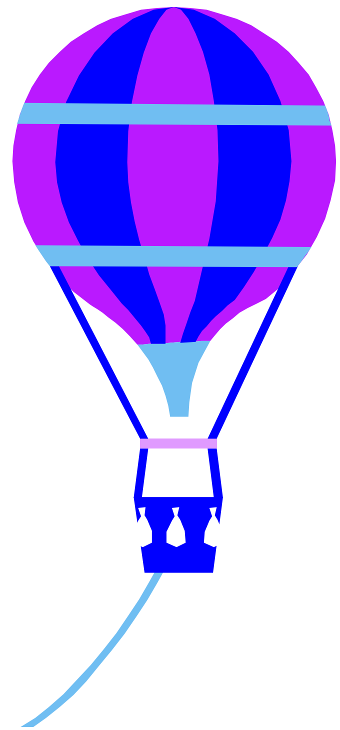
Expansion Ratio





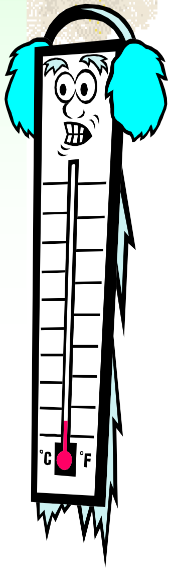
Expansion Ratios of Cryogenics

Flourine	981 : 1
Oxygen	862 : 1
Hydrogen	840 : 1
Helium	754 : 1
Nitrogen	697 : 1
LNG	637 : 1



Cryogenics

- ***Liquefied Refrigerated gases with boiling points less than** -130°F*



Helium *-452°F*

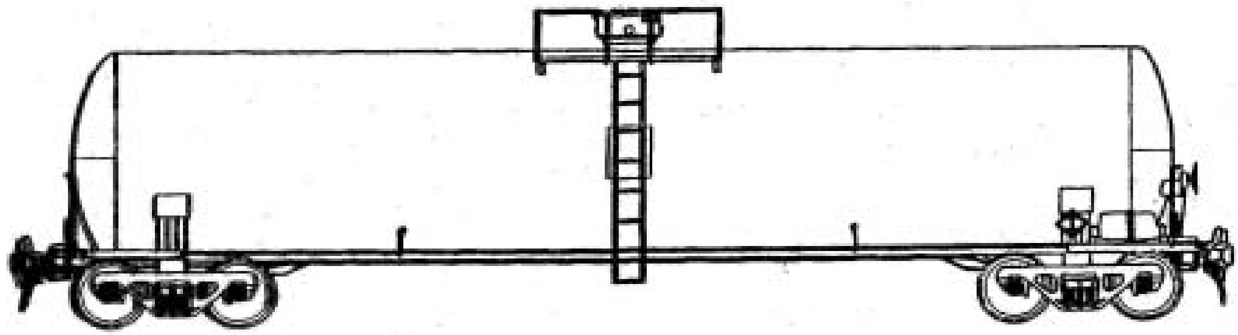
Nitrogen *-*
321°F

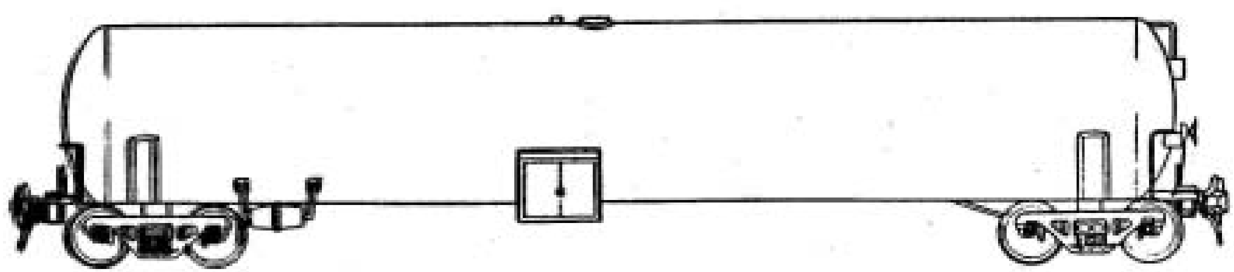
Oxygen *-291°F*

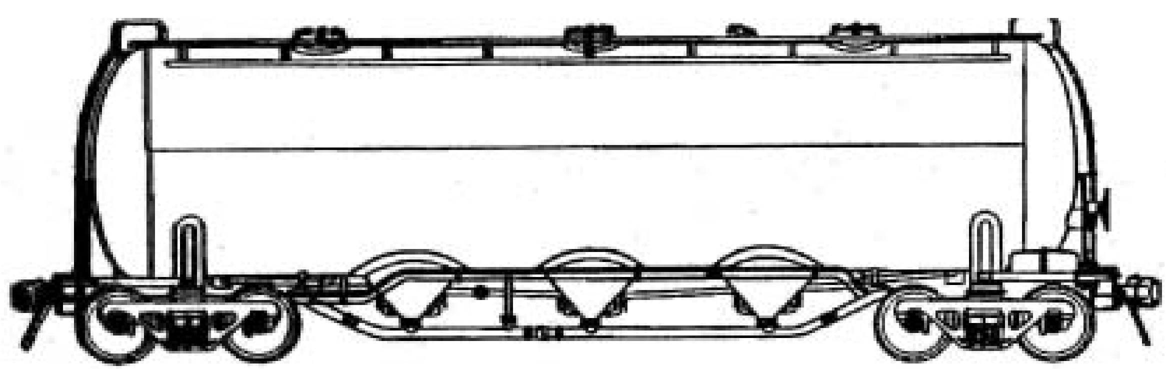
Hydrogen *-*
423°F

Physical Form

- **Surface Area**
  - **extremely important to consider**
  - **very finely divided particles**
  - **sawdust, grain dust, flour, coal dust**
  - **not regulated by DOT**

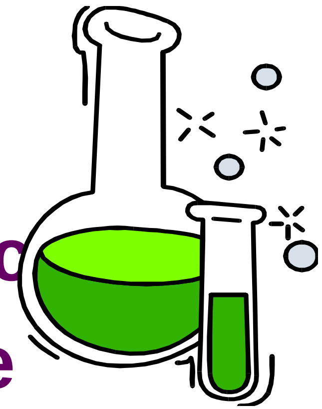




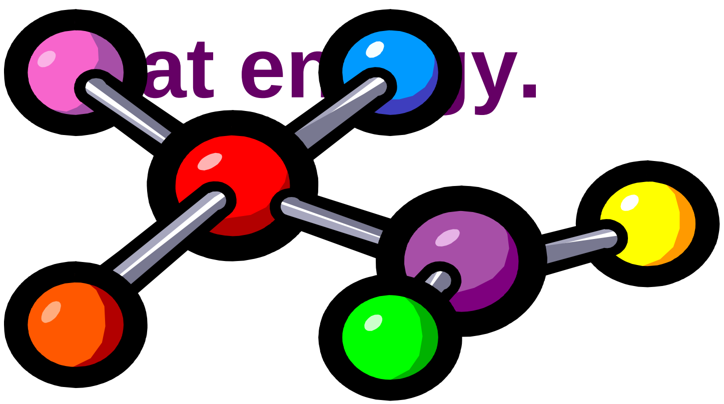


Chemical Change

- Chemical Reaction
  - result in a new substanc
  - are not easily reversible



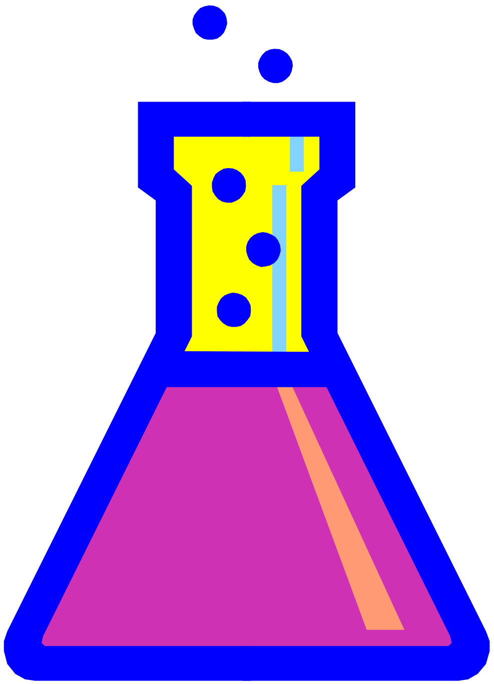
- Chemical reactions involve a change in at en y.



$$2H_2 + O_2 \rightarrow 2H_2O$$

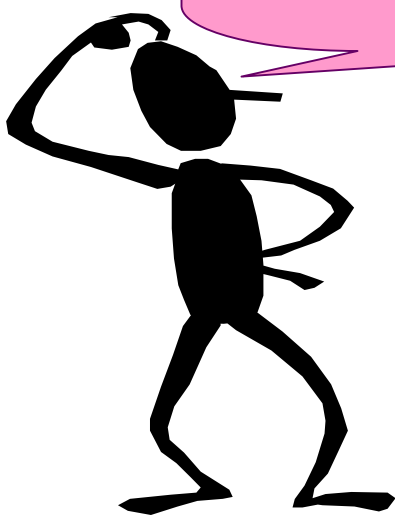
chemical reactions

- 3 types:
  - Combination
  - Decomposition
  - Displacement
    - single replacement
    - double replacement



$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

? Displacement, Combination



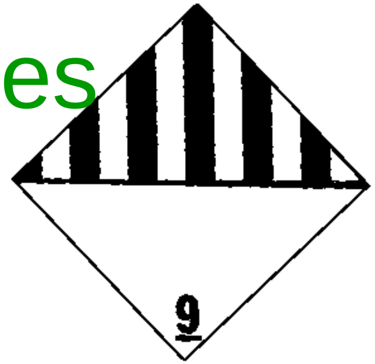
$$2H_2 + O_2 \rightarrow 2H_2O$$

Why is it "Hazardous" ?

- Hazardous to Life
  - carcinogen, teratogen, asphyxiant, sensitizer
  - neurotoxin, hemotoxin, nephrotoxin
- Hazardous to Environment
  - gases, particulates
  - oxygen demanding, plant nutrients, bioaccumulative
  - municipal solid waste, hazardous waste
- Hazardous to Property
  - NFPA 704 system, **DOT hazard classes**

Miscellaneous Hazardous Materials

- Class 9
  - elevated temperature materials
  - hazardous substances
  - marine pollutants
  - hazardous waste
    - asbestos, castor beans, cotton, sulfur
    - iodine - hazardous waste solid, n.o.s.



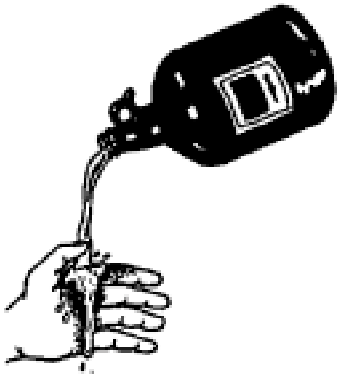
Consumer Commodities

– Materials that are packaged in a form intended for sale through retail agencies for consumption by individuals

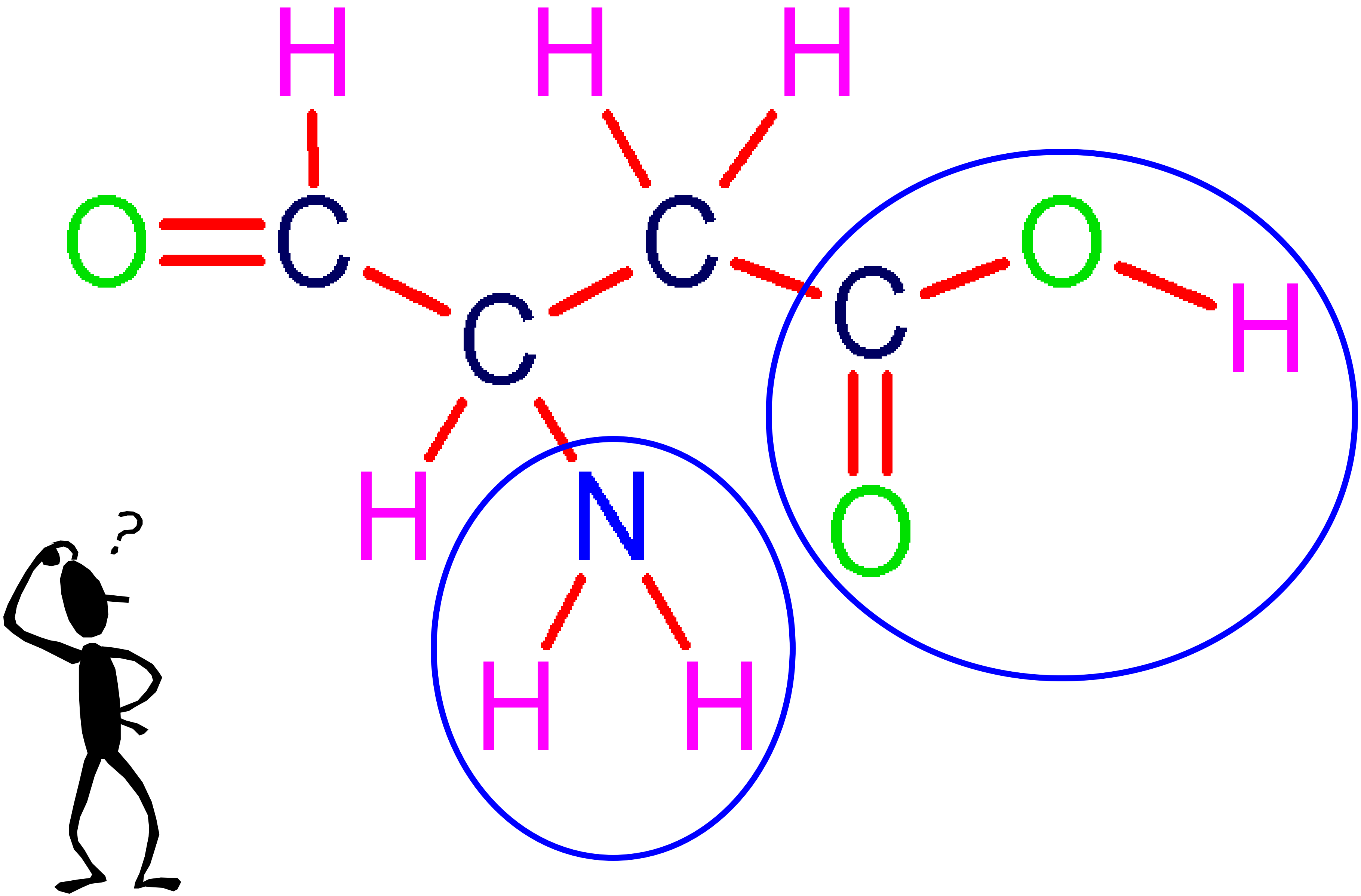
– The flammability of aerosols is determined by the criteria in 49 CFR 173.306 as, “using B.O.E.’s Flame Projection Apparatus, the flame projects greater than 18” beyond the ignition source”

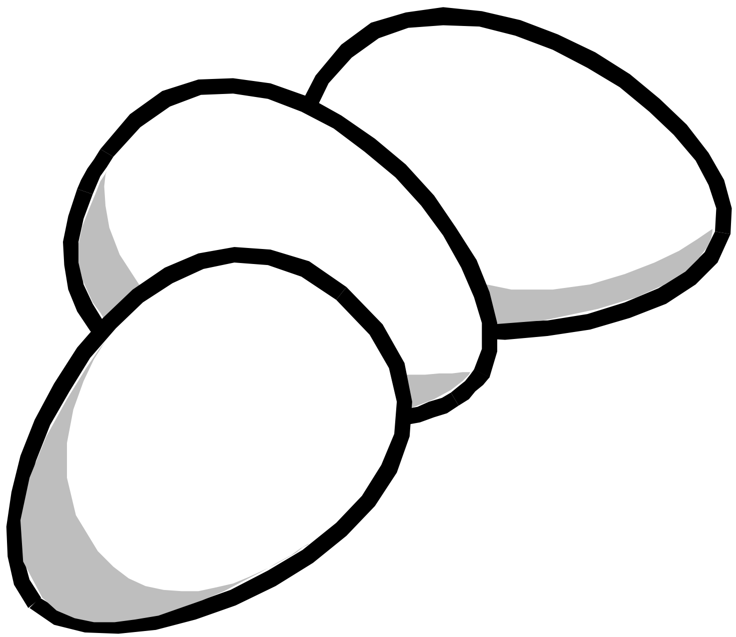
Corrosives

- **Definition:**
  - **A *corrosive* material means:**
  - "a liquid or solid that causes full thickness destruction of human skin at the site of contact."



"a liquid that has a severe corrosion rate on steel or aluminum."





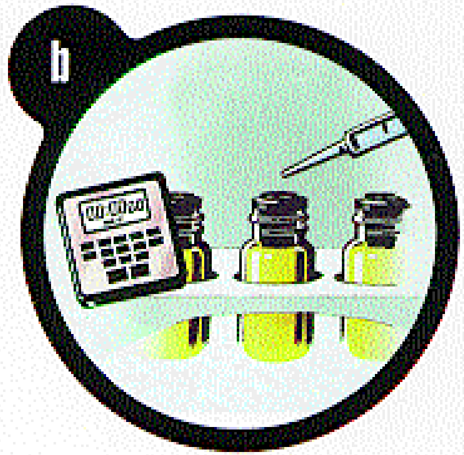
Corrosives

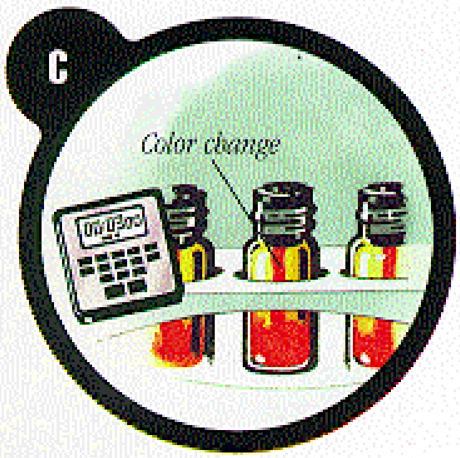
– *Packing Groups 1, 2 & 3……*

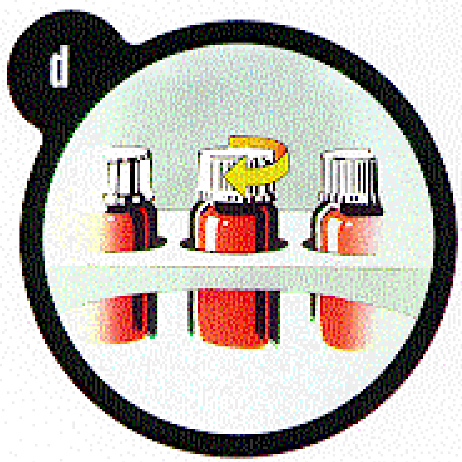
– causes *full thickness destruction* of skin tissue within an observation period of:

1 hour after an exposure of 3 minutes or less

14 days after an exposure of 3 to 60







a Place one (prepared and refrigerated) Biobarrier Disc in the top of each vial. Begin test immediately (no later than 2 minutes).

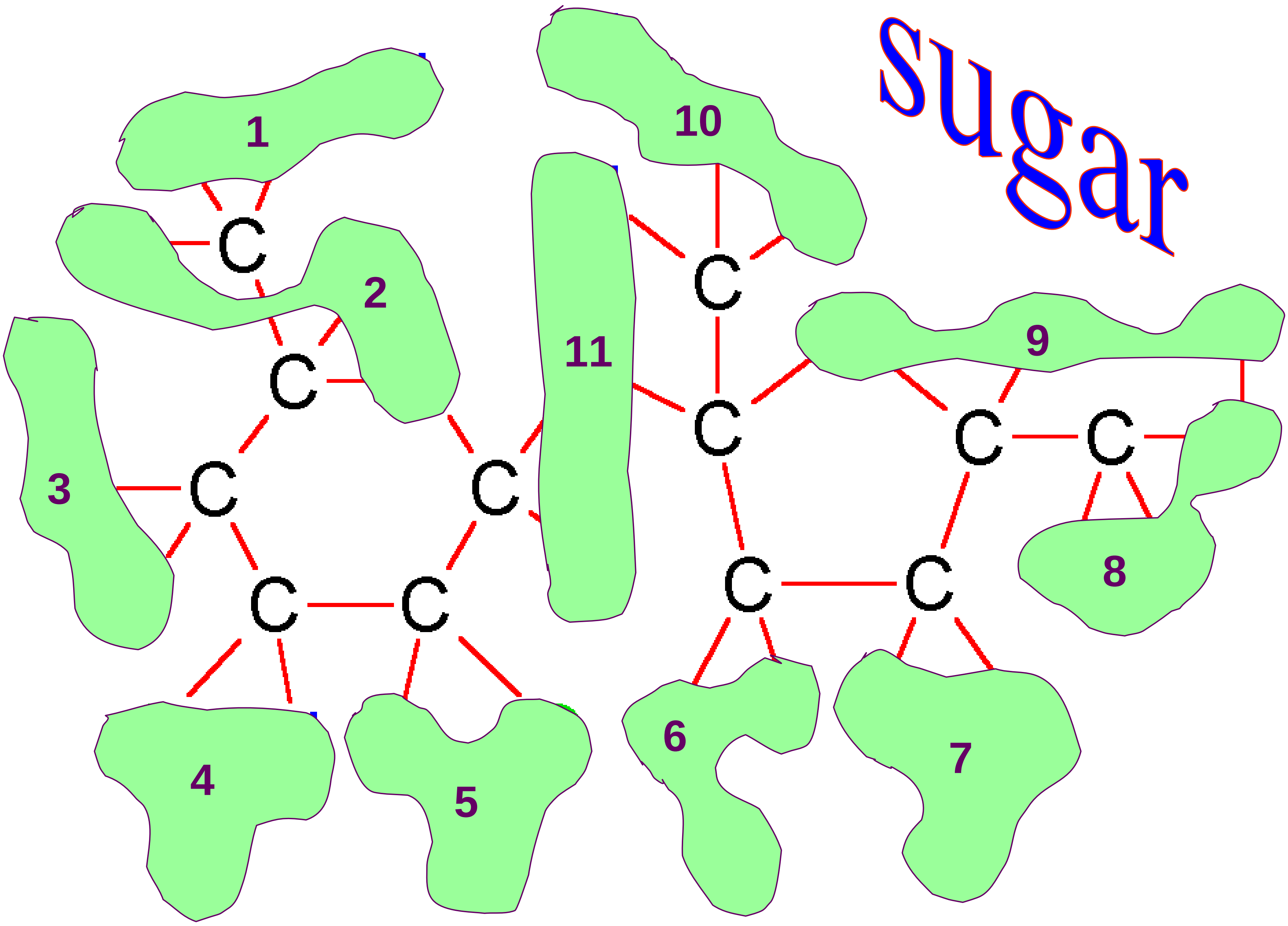
b Add 500 µl (liquid) or 500 mg (solid) of your test sample and control chemicals into Biobarrier Discs in each of the 6 vials and start timers. *Caution: Do not cap the vials during the test due to possible pressure build up.*

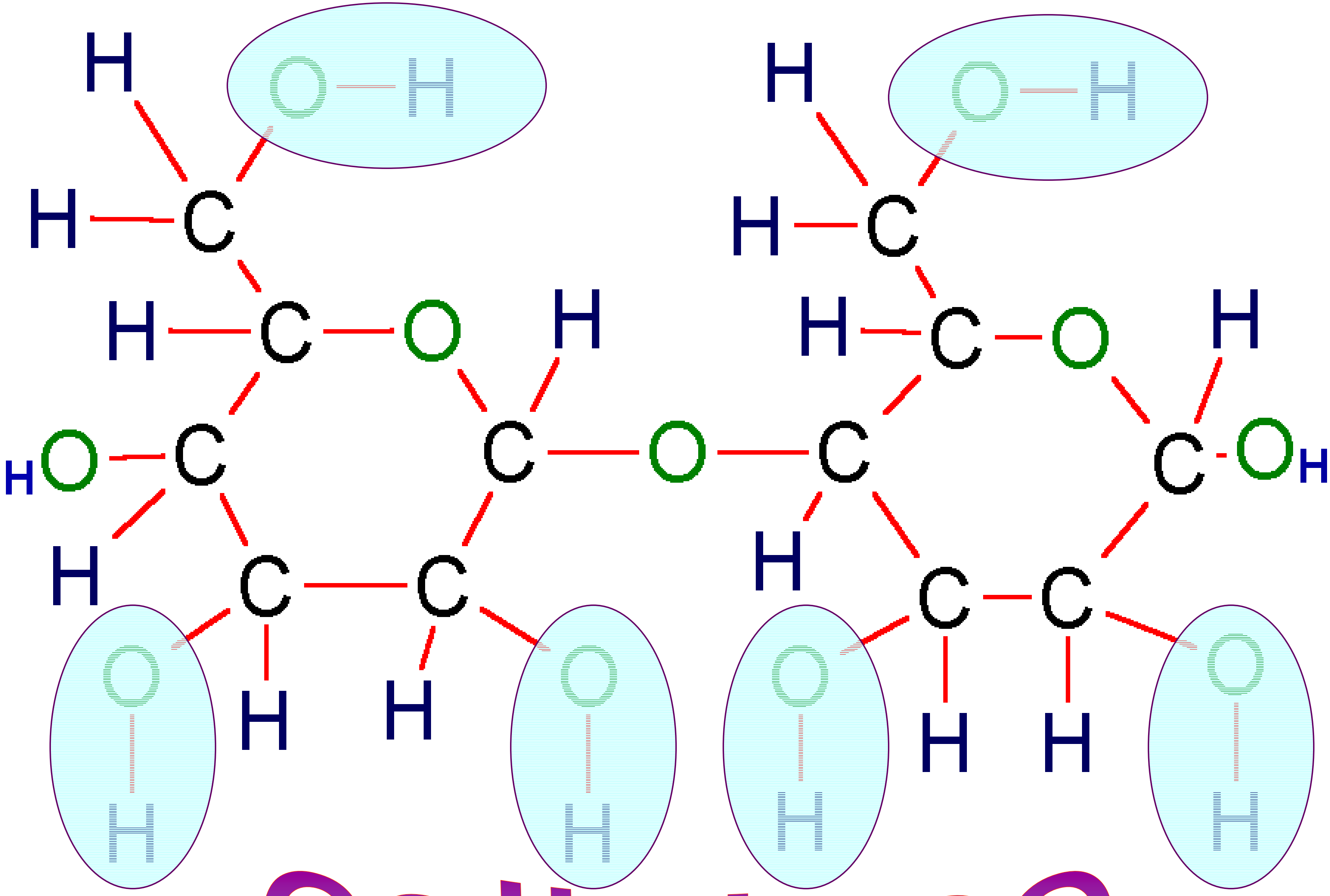
c As soon as a reaction is observed in the Chemical Detection System, record the detection time.

d Remove each Biobarrier Disc, cap and dispose of vials using your lab protocol for proper chemical disposal.

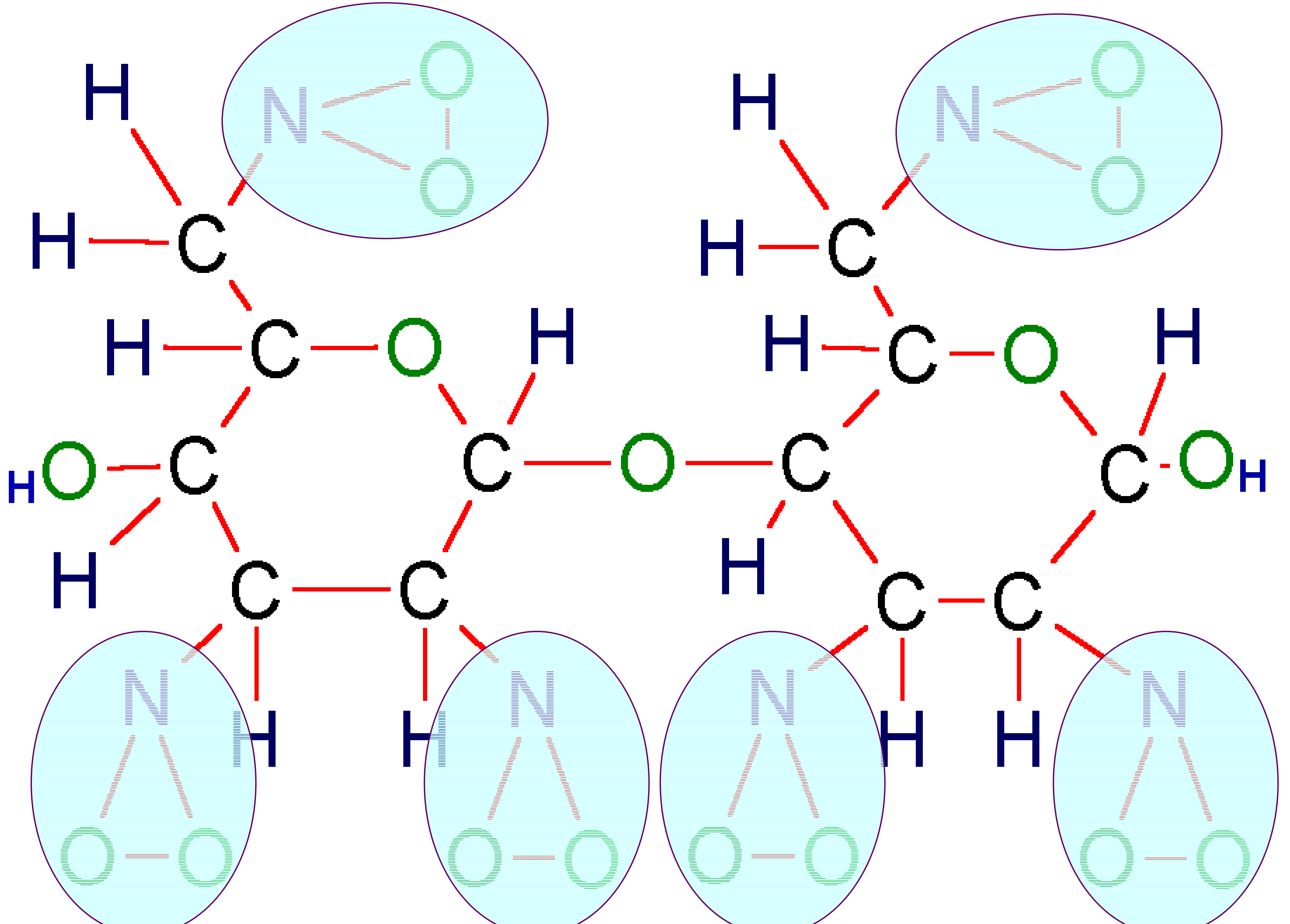
$Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$

what's N_2O?


sugar
1
2
3
4
5
6
7
8
9
10
11



Cellulose

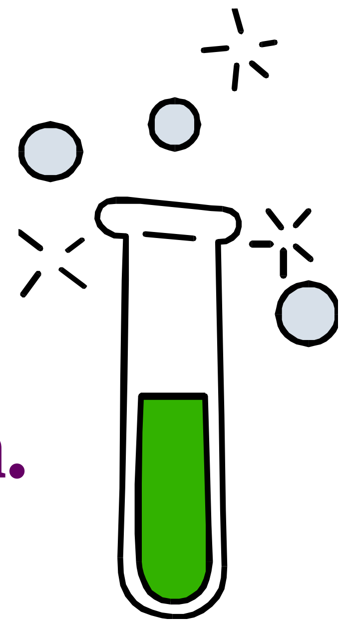


H
N
O
O
H
C
H
H
C
O
H
H
O
C
C
O
C
C
H
H
C
C
N
N
H
H
O
O
O
O
H
N
O
O
H
C
H
H
C
O
H
C
O
H
H
C
C
N
N
H
H
O
O
O
O

Is it Hazardous Waste?

- **A solid waste exhibits the characteristic of corrosivity if a representative sample of the waste is:**
  - **Aqueous, with a pH less than or equal to 2.0, or greater than or equal to 12.5**

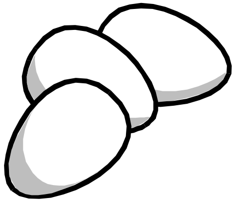
What is pH ??



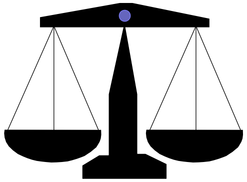
- **a value that represents the acidity or alkalinity of an aqueous solution.**
- **the negative logarithm of the molar hydrogen ion concentration.**
- **Now, <u>WHAT</u> did you say ?…**

What's a Mole ?

- How do we buy buy eggs ?
  - By the dozen



- How do we buy rice ?
  - By the pound



- Mole:
  – a convenient way of measuring atoms
  – equals Avogadro's # of molecules or atoms
  – equals molecular weight or atomic weight
    - expressed in grams

The pH scale

- logarithmic
- intervals are exponential
- each unit is equivalent to a ten-fold difference from the unit before it
- a pH 1 is how many times more acidic than a pH 3?, a 4?

pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
H^+ ions	10^0	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}

How Do We Measure pH ?

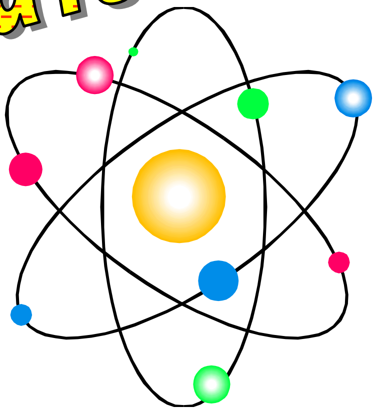
- pH paper is the most common
- Indicator Solutions
- pH meter

The pH of Common Fluids

Fluid	pH
Stomach Acid	1.5
Lemon Juice	2.4
Vinegar	3.0
Orange Juice	3.5
Urine	6.0
Saliva	6.7

Fluid	pH
Milk	6.5
Pure water	7.0
Blood	7.4
Bile	8.3
Milk of Magnesia	10.6
Ammonia	11.5

Radioactive Materials



any material having a *specific activity* > .002 microcurie/gram

activity = # of disintegrations per second

Radioactive Isotopes

- Atoms of the same element containing a different number of *neutrons* in the nucleus

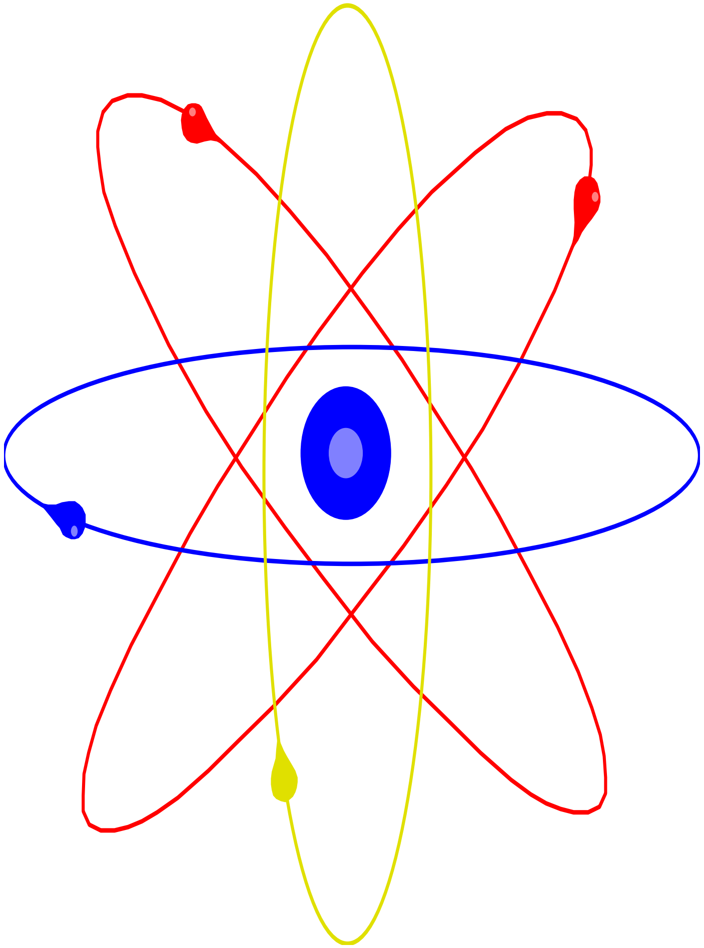


Table of Radioactive Isotopes (Continued)

Element	A	Half-life	Radiation (MeV)
	229	7340y	α(4.90, 4.84, 4.81), Ra-x, γ(0.137, 0.20)
	*230(Io)	7.54×10^4y	α(4.68, 4.62), Ra-x, γ(0.068)
	*231(UY)	1.0633d	β^-(0.302, 0.218, 0.138), Pa-x, γ(0.026, 0.084)
	*232(Th)	1.405×10^{10}y	α(4.01, 3.95), γ(0.059)
	*234(UX_1)	24.10d	β^-(0.199, 0.104), Pa-x, γ(0.029, 0.063, 0.092, 0.093, 0.113)
Protactinium	228	22h	K, α(6.11, 6.08, 6.03, 5.80), Th-x, γ(0.410, 0.463, 0.965, 0.969)
	229	1.4d	K, α(5.67, 5.62, 5.58, 5.54), Th-x
	230	17.4d	K, β^-(0.509), α(5.34, 5.33, 5.31, 5.30), Th-x, γ(0.444, 0.455, 0.899, 0.919, 0.952)
	*231(Pa)	3.276×10^4y	α(5.06, 5.02, 5.01, 4.95, 4.73), Ac-x, γ(0.027, 0.284, 0.300, 0.303)
	232	1.31d	β^-(0.32, 1.19, 1.30), U-x, γ(0.150, 0.894, 0.969)
	233	27.0d	β^-(0.257, 0.15, 0.568), U-x, γ(0.312)
	*234m(UX_2)	1.17min	β^-(2.29), IT, U-x, γ(0.765, 1.00)
	*234(UZ)	6.70h	β^-(0.68, 0.51, 0.28), U-x, γ(0.131, 0.570)
Neptunium	231	48.8min	K, α(6.28), γ(0.264, 0.348, 0.371), no β^+
	[illegible]	[illegible]	[illegible]
	233	36.2min	K, α(5.54), U-x, γ(0.299, 0.312)
	234	4.4d	K, β^+(0.8), U-x, γ(1.528, 1.559, 1.602)
	235	1.085y	K, α(5.02), U-x, γ(0.026, 0.084)
	236	22.5h	K, β^-(0.537), U-x, γ(0.045, 0.643, 0.688)
	236	1.550×10^5y	K, β^-, γ(0.160)
	237	2.140×10^6y	α(4.79, 4.77), Pa-x, γ(0.029, 0.086)
	238	2.117d	β^-(1.24, 0.28, 0.25), γ(0.984, 1.026, 1.029)
	239	2.355d	β^-(0.437, 0.332, 0.393, 0.713), Pu-x, γ(0.106, 0.228, 0.278)
	240m	7.22min	β^-(2.18, 1.60, 1.30), γ(0.555, 0.597)
	240	1.032h	β^-(0.89), γ(0.448, 0.566, 0.974)
	241	13.9min	β^-(1.4), γ(0.135, 0.175), no α
	241	3.4h	β^-

Protection Factors

- Approach a spill using
  - Time
  - Distance
    - inverse square law
  - Shielding
- and the "ALARA principle"

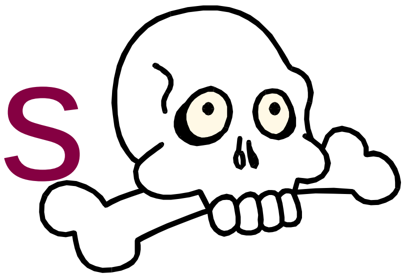
Radioactive - Yellow II

- Transport Index
  > 0 but < 1
- Surface readings
  > 0.5mrem/hr
  < 50mrem/hr

Poisons - Class

- Materials,
  other than gases,
  known to be so toxic to
  humans that they afford
  a hazard to health during
  transportation…………..

Poisons - Class



Presumed to be Toxic to Humans

Acute Toxicity (Testing on Lab Animals)

Oral LD50 for liquids < 500 mg/Kg

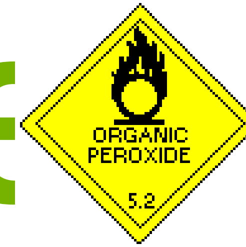
for solids < 200 mg/kg

Acute dermal LD50 < 1,000 mg/Kg

Acute inhalation LC50 < 10 mg/L

as a dust or mist

Oxidizers



- An oxidizer as defined in 49CFR,

  “a material that may,
  generally by yielding oxygen,
  cause or enhance the
  combustion of other materials.”

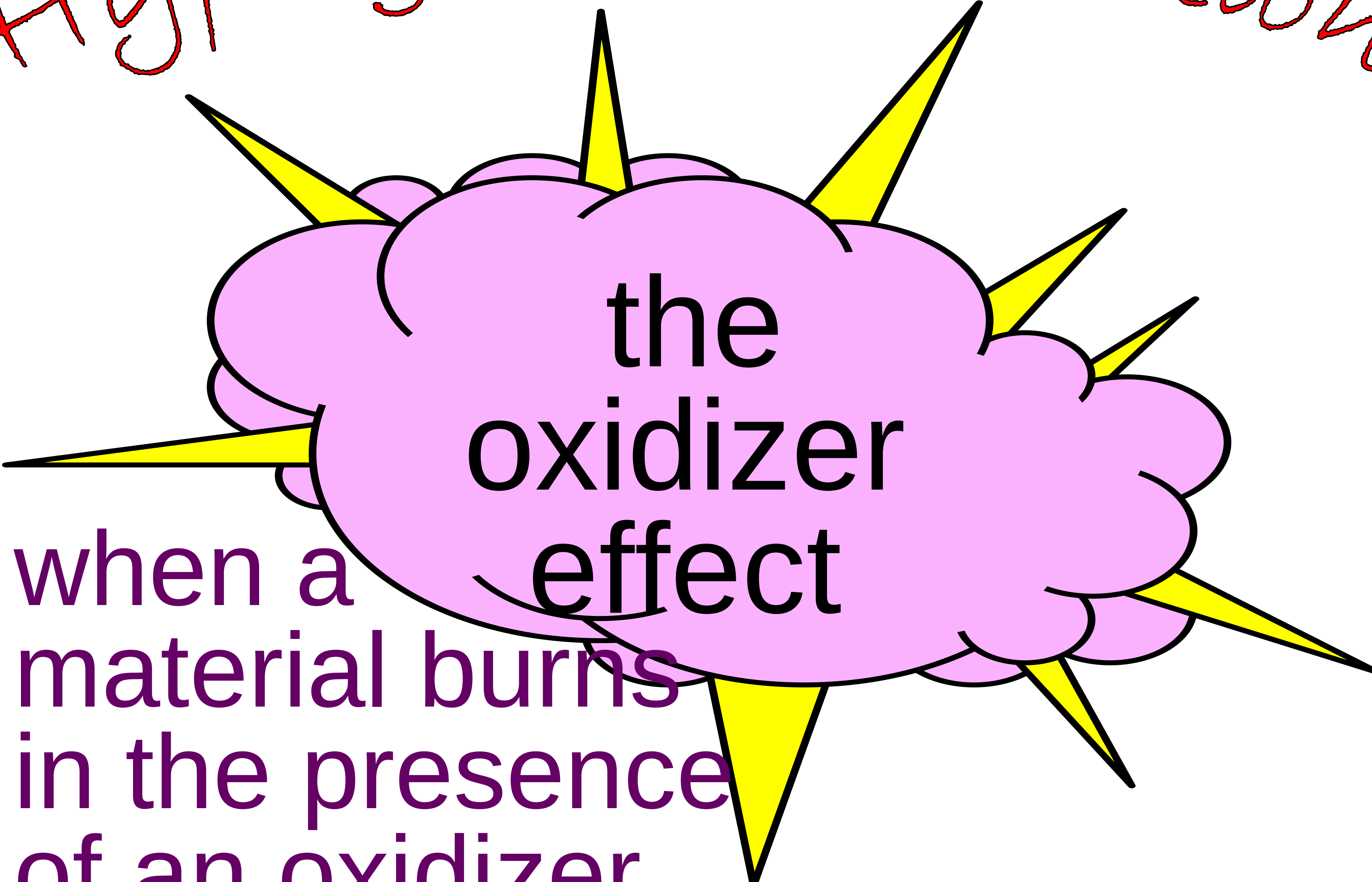
- Oxidizers as a class, are reactive
  and support combustion through
  the release of oxygen, heat or both.

Let’s take a look at some oxidizers!!!!

Inorganic Oxidizers

- Oxygen
- Oxy-Salts
- Halogens
- Oxy-Acids
  - Nitric acid
  - Chromic acid
  - Perchloric acid
- Metal Peroxide Salts

Hypergolic Combustion



when a material burns in the presence of an oxidizer

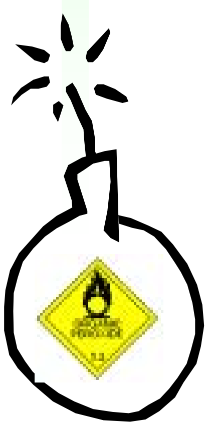
Inorganic Oxidizers

- ☑ Oxygen
- ☑ Oxy-Salts
- ☑ Halogens
- ☑ Oxy-Acids
  - Nitric acid
  - Chromic acid
  - Perchloric acid
- ☑ Metal Peroxide Salts

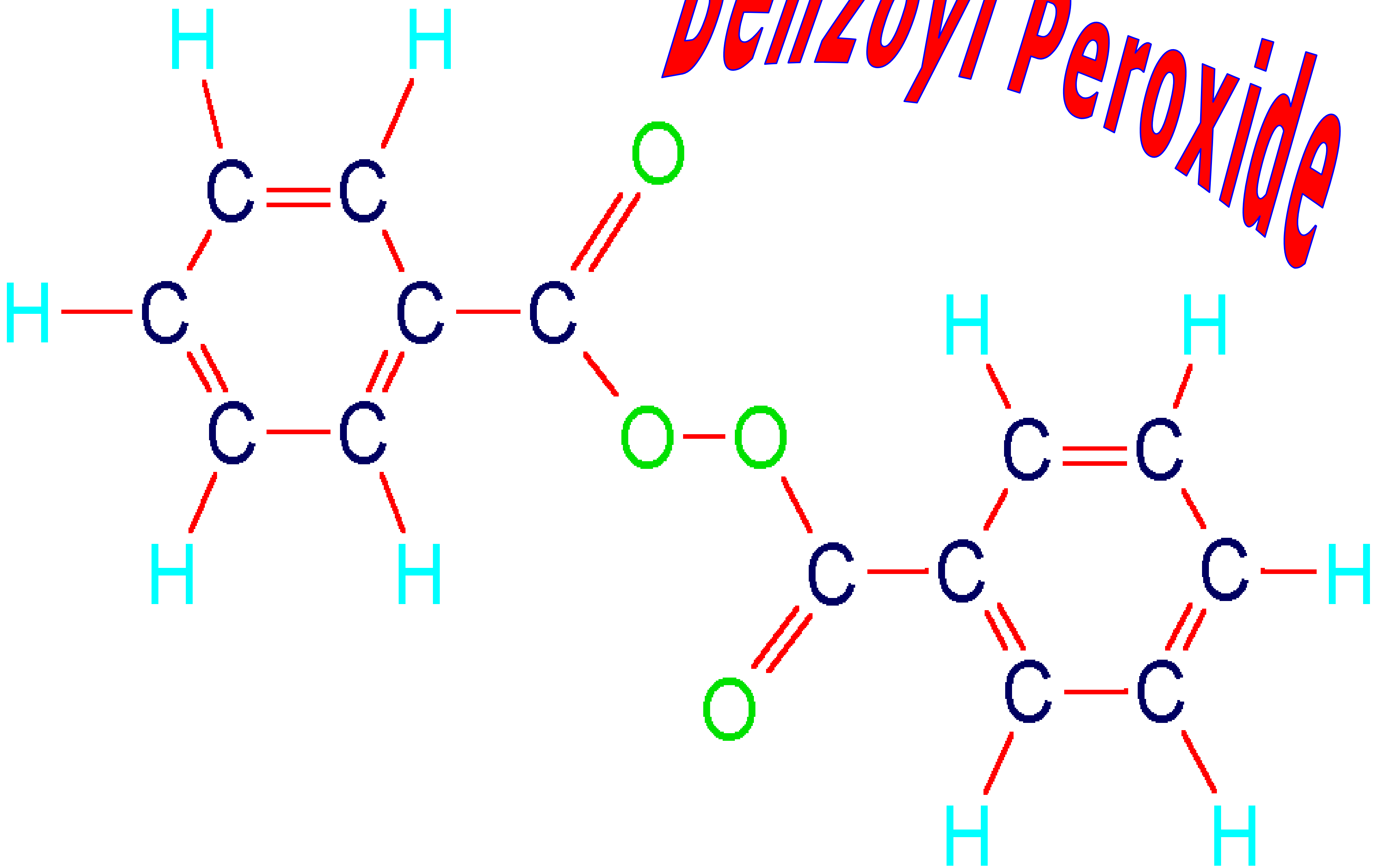
Organic Peroxides

- Mainly used as initiators and catalysts for plastics manufacturing.
- Their explosive nature and their character as ***unstable fuels*** are more serious than their hazards as oxidizers.
- Some are normally unstable

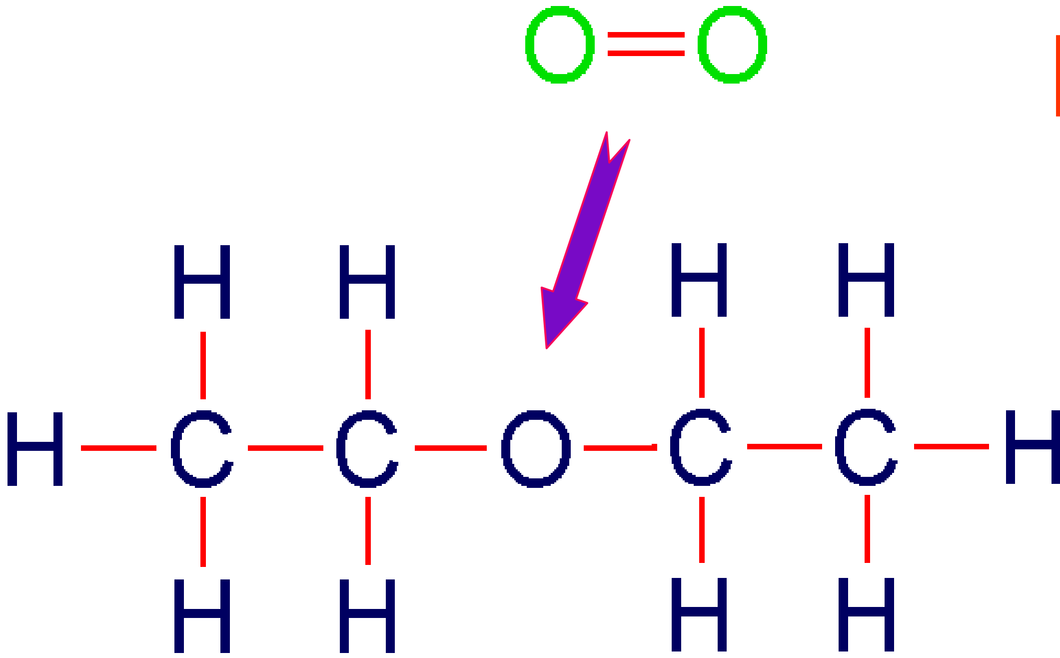
  and can undergo violent change;

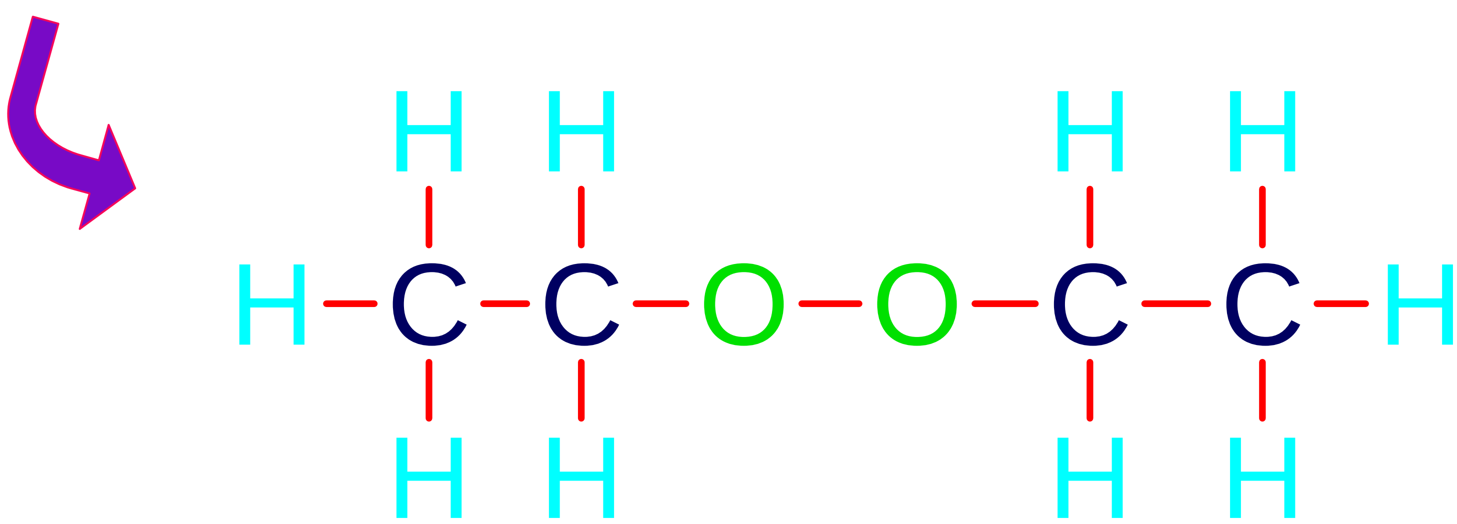


Benzoyl Peroxide



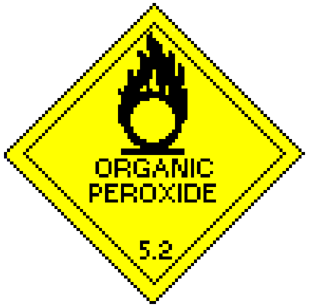
Formation of Peroxides





A Recognition Clue

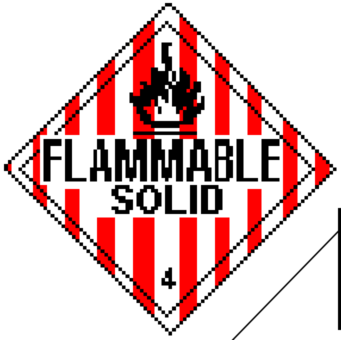
- If the compound name has;
  - “hypo”______
  - “per”_______
  - ______”ate”
  - ______”ite”
  - ______”peroxide”
  - or peroxy as part of it,
- **Treat it as an oxidizer!!**

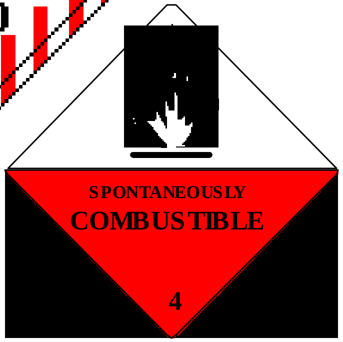


Flammable Solids

- DOT Definitions

  three divisions:





4.1 Flammable Solid

4.2 Spontaneously Combustible

4.3 Dangerous When Wet Material

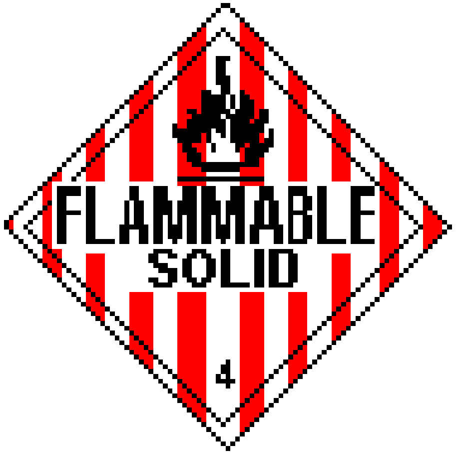
Flammable Solids

either wetted explosives, thermally unstable self reactive materials, solids that may cause fire through friction, or solids that burn vigorously above a certain rate of burn.

Let’s look at some properties of flammable solids!!!

Flammable Solids

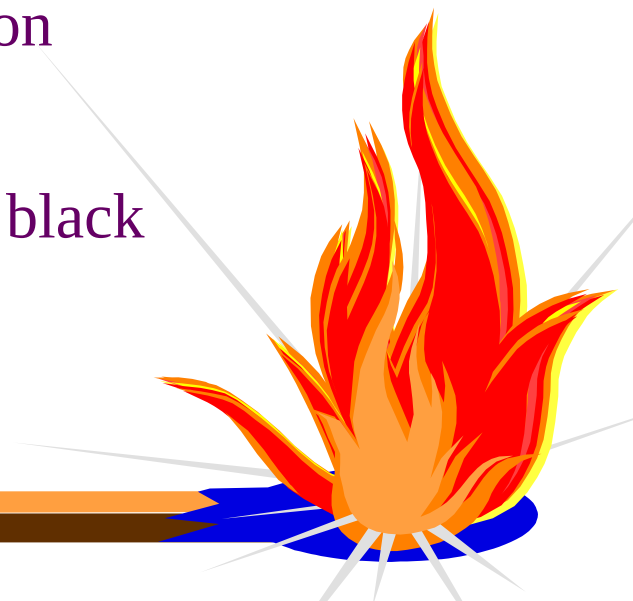
- **Flammable Metals**
  - ***Magnesium*** - ribbons
  - ***Aluminum*** - powder
  - ***Cerium*** - ingots
  - ***Zirconium*** - sheets



Flammable Solids

Flammable Non-Metals

- sulfur
  - ingredient in black powder
  - SO_2 is product of combustion
- phosphorous
  - 3 allotropes - white, red, or black
  - white - pyrophoric,
    stored under water

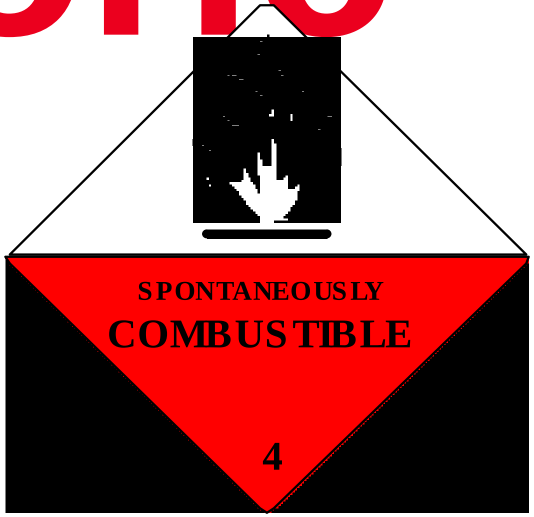


Spontaneously Combustible

•Pyrophoric

Materials

- ignite spontaneously within 5 minutes after coming in contact with air



- Diethyl Zinc, White Phosphorous, Potassium Sulfide, Pentaborane

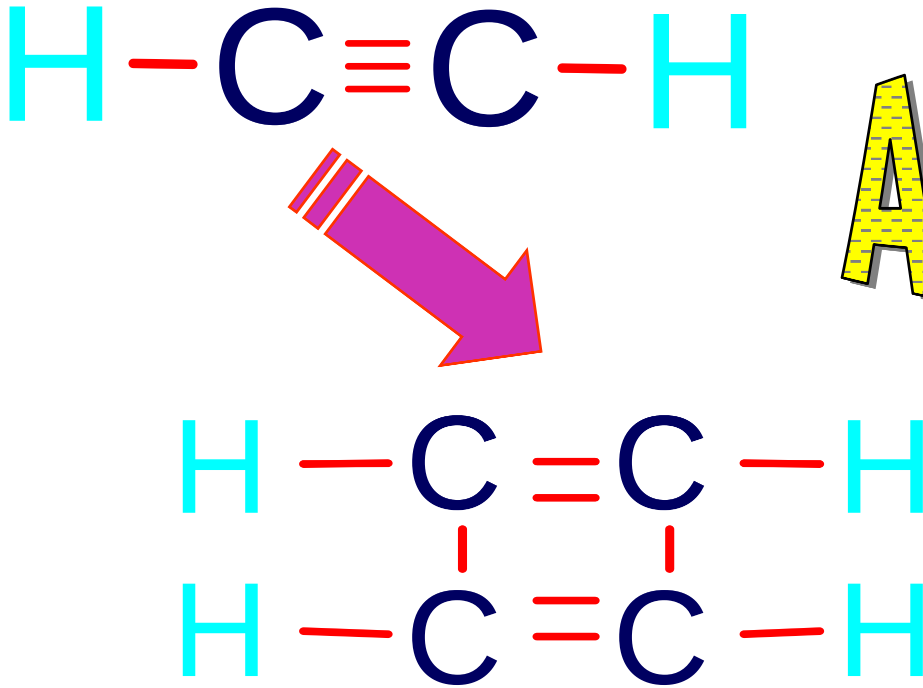
Dangerous when Wet

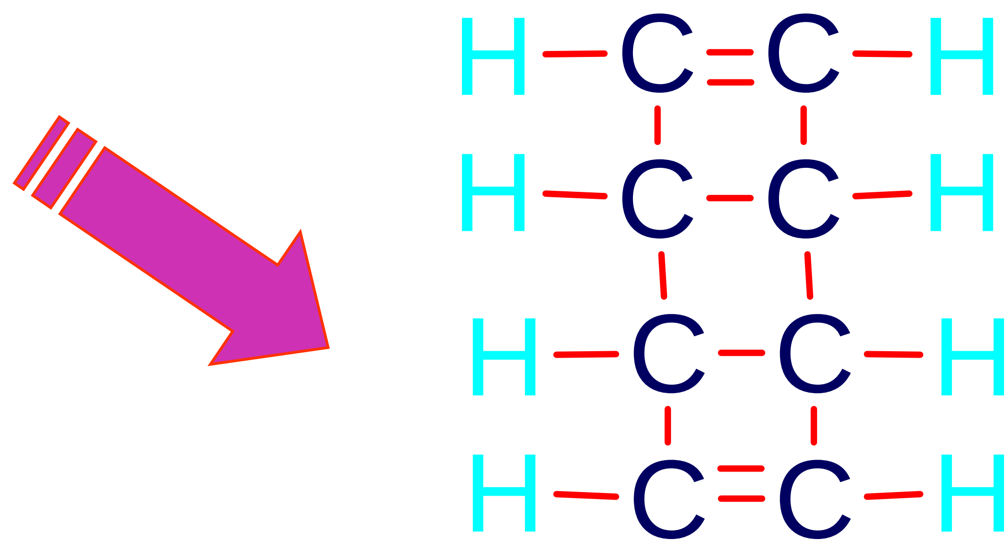
– A material that, by contact with water, is liable to become spontaneously flammable or to give off flammable or toxic gas

– reacts violently with water

– forms potentially explosive mixtures with water

Acetylene



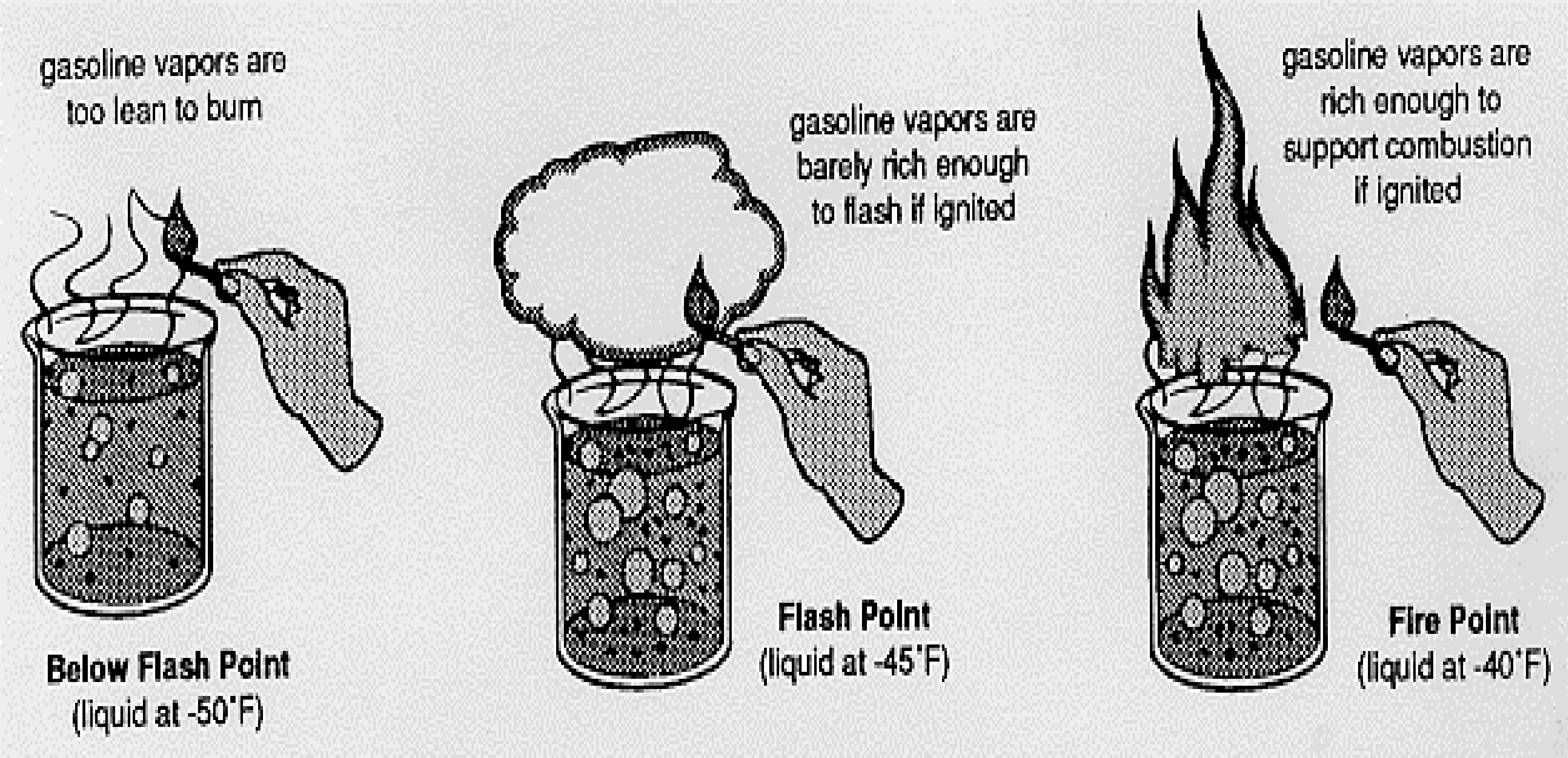


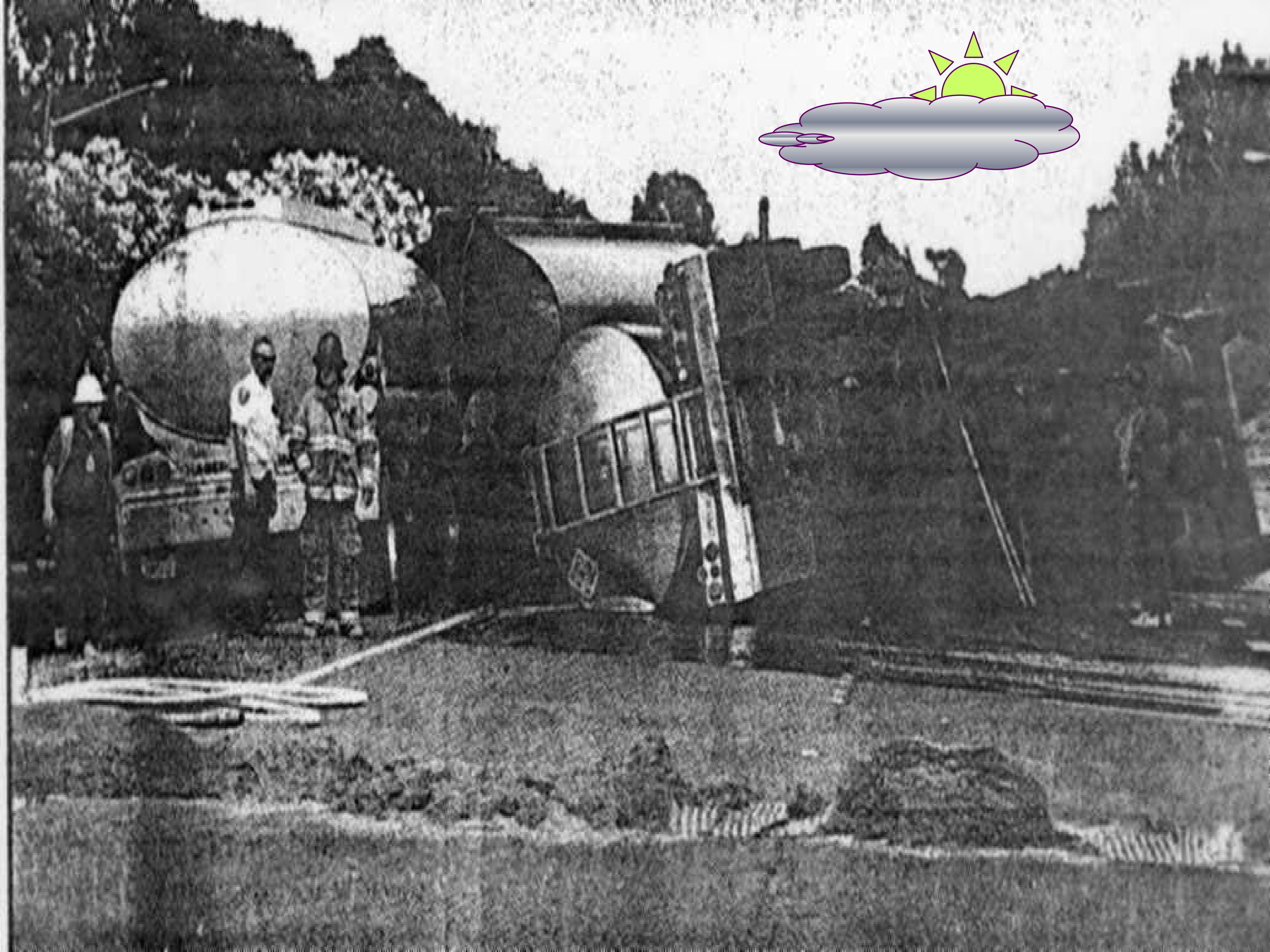
flammable liquids

Flammable Liquid - flashpoint < 141°F

Combustible Liquid - flashpoint > 141°F

Let's look at some properties of flammable & combustible liquids!!!


gasoline vapors are too lean to burn
Below Flash Point
(liquid at -50°F)
gasoline vapors are barely rich enough to flash if ignited
Flash Point
(liquid at -45°F)
gasoline vapors are rich enough to support combustion if ignited
Fire Point
(liquid at -40°F)



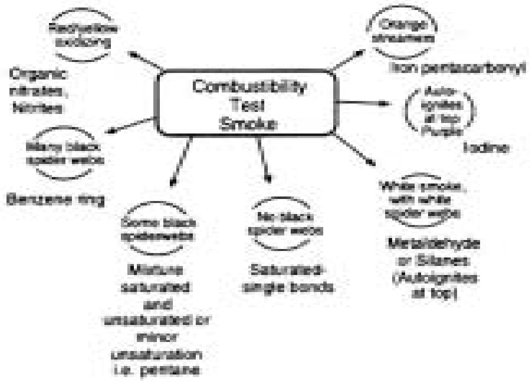
1. Viscosity

Viscosity is a function of one of 6 things.

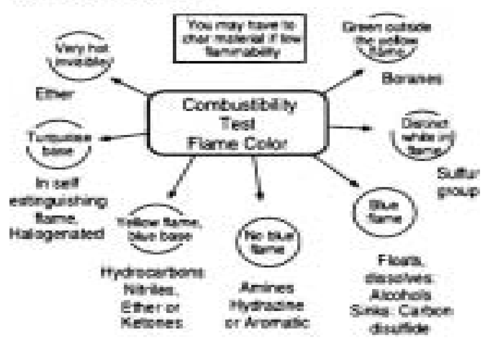
1. Carbon chain length (separates from water with a distinct line):
   - 1 to 10 carbons - viscosity 1
   - 11 to 18 carbons - viscosity 2
   - 20 to 25 carbons - viscosity 3
   - 29 carbons - viscosity 4

   One functional group on a long-chain organic will change the viscosity, causing the liquid to become more viscous.
2. Multiple functional groups (dissolve in water): The greater the number of functional groups, the more viscous the material.
3. The material is partly polymerized (Curdles or becomes stringy in water)
4. The material is a gel (remains unchanged in water, may appear to disappear or hang in water, neither floating nor sinking).
5. A solid or viscous liquid is dissolved in liquid (Separates into various components in water)
6. Glasses, usually silicates, NOT organic.

2. Smoke Colors



3. Flame Colors

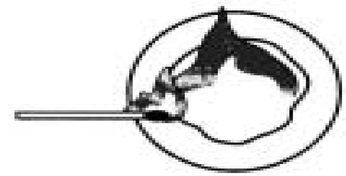


Hazardous waste with a Flash Point below 140 F is condidered to be **Ignitable**. There are two main methods for determining flash point - Open and Closed cup. The method below is not exact enough to establish a legal classification of **Flammable** and/or **Combustible**, but it will give you a field estimation of how flammable the material is. These estimates are given for interpreting the HazCat charts only.

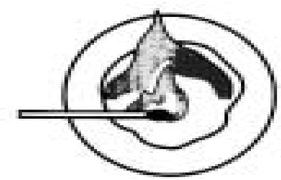
Place a puddle the size of a 50-cent piece on the watch dish. Slowly move a lit match (starting from 2 inches away) towards the watch dish, keeping it level with the dish. If the liquid bursts into flame before the match reaches the edge of the watch dish, or as it reaches the dish (this test will be influenced by temperature and air movement), the flash point is below 20 F. **Extremely Flammable**

If, as you barely touch the puddle of liquid on the watch dish, it bursts into flame, the flash point is below 50 F. To be certain that you are erring on the safe side, consider as **Extremely Flammable**.

If you touch the puddle, and the liquid ignites fairly quickly, the flash point is below 60 F. **Flammable**



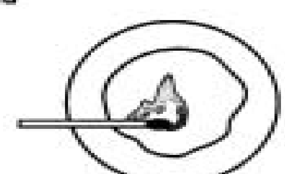
If the material first soaks into the match, where it quickly wicks, and then steadily covers the total surface area of the liquid with flame, the flash point is below 70 F. **Flammable**

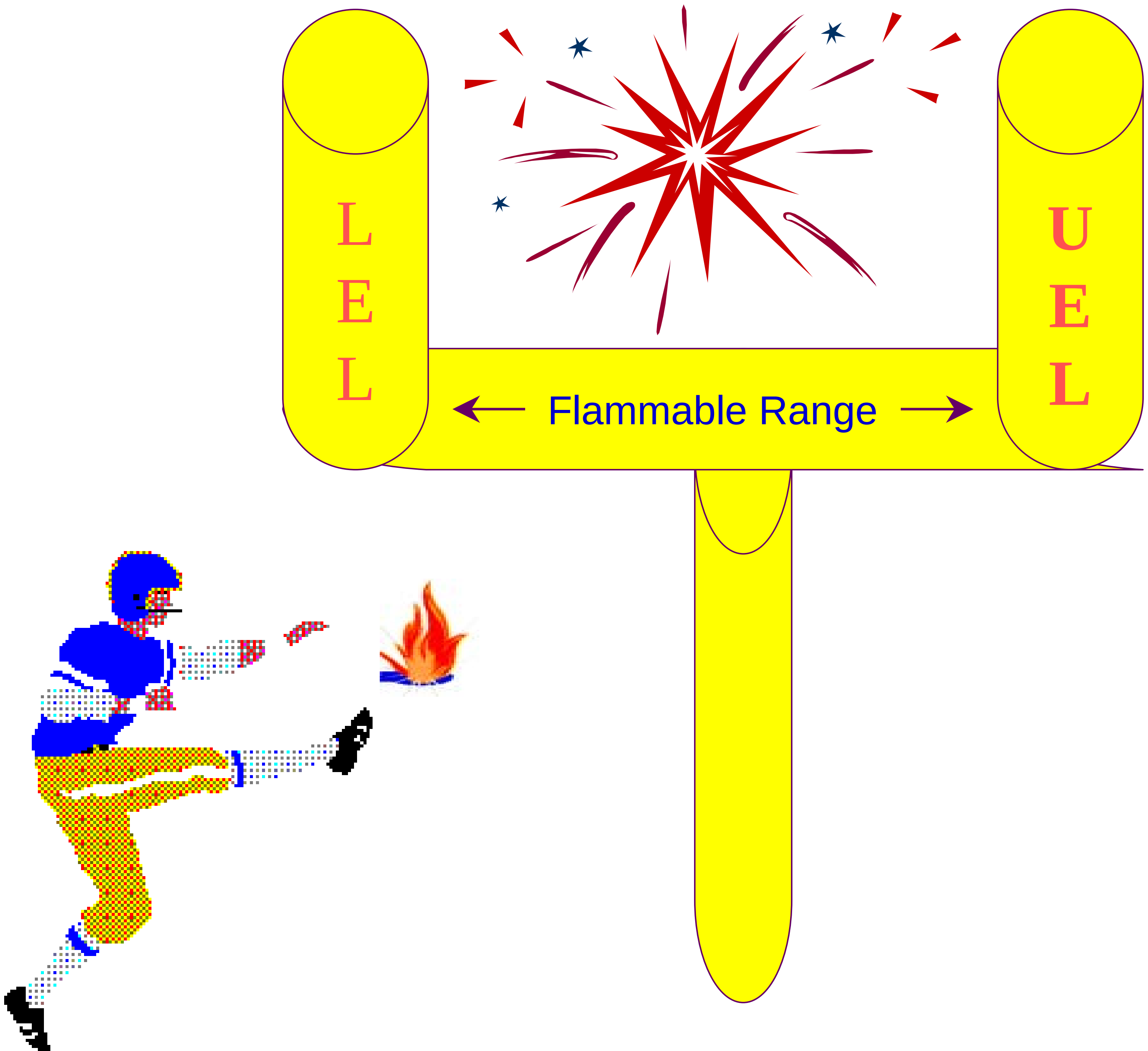


If the material flashes slightly, wicks and then the flame spreads over the whole surface of the puddle reluctantly, the flash point is below 90 F. **Flammable**

Warning: Consider any flashing of the liquid, sustained or not, as an indicator that the liquid has a flash point under 100 F.

If the material wicks slowly and steadily, but the flame will not spread over the surface of the liquid, the flash point is above115 F. **Combustible** for HazCat, but for safety - **Treat as Flammable**



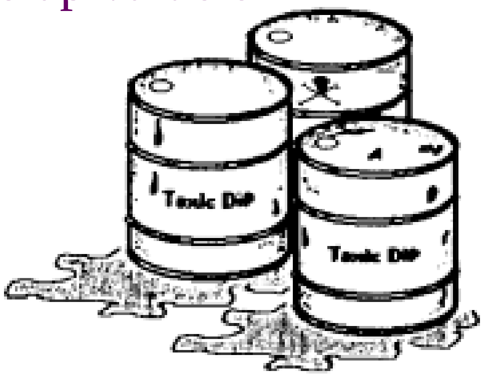

LEL
UEL
Flammable Range

What About Empty Containers?

- Adopted CA standards require generator to empty all the material possible from the container.

<u>Container Management</u>

- **Larger than five gallons**
  - within 1 year - reclaim scrap value or recondition
- **Five gallons or less**
  - disposed at appropriate facility, reclaim scrap value or recondition
- **Household containers**
  - only exempt if empty of all contents



What About Empty Containers?

The moral of the story is…

- **"Empty" containers will contain some residual hazardous materials which could cause significant harm if mismanaged.**

- **The contaminated container regulations do not classify the containers as non-hazardous at any stage, they only grant an exemption. NEVER *ass*ume a container is non-hazardous.**

Compressed Gases - Class 2

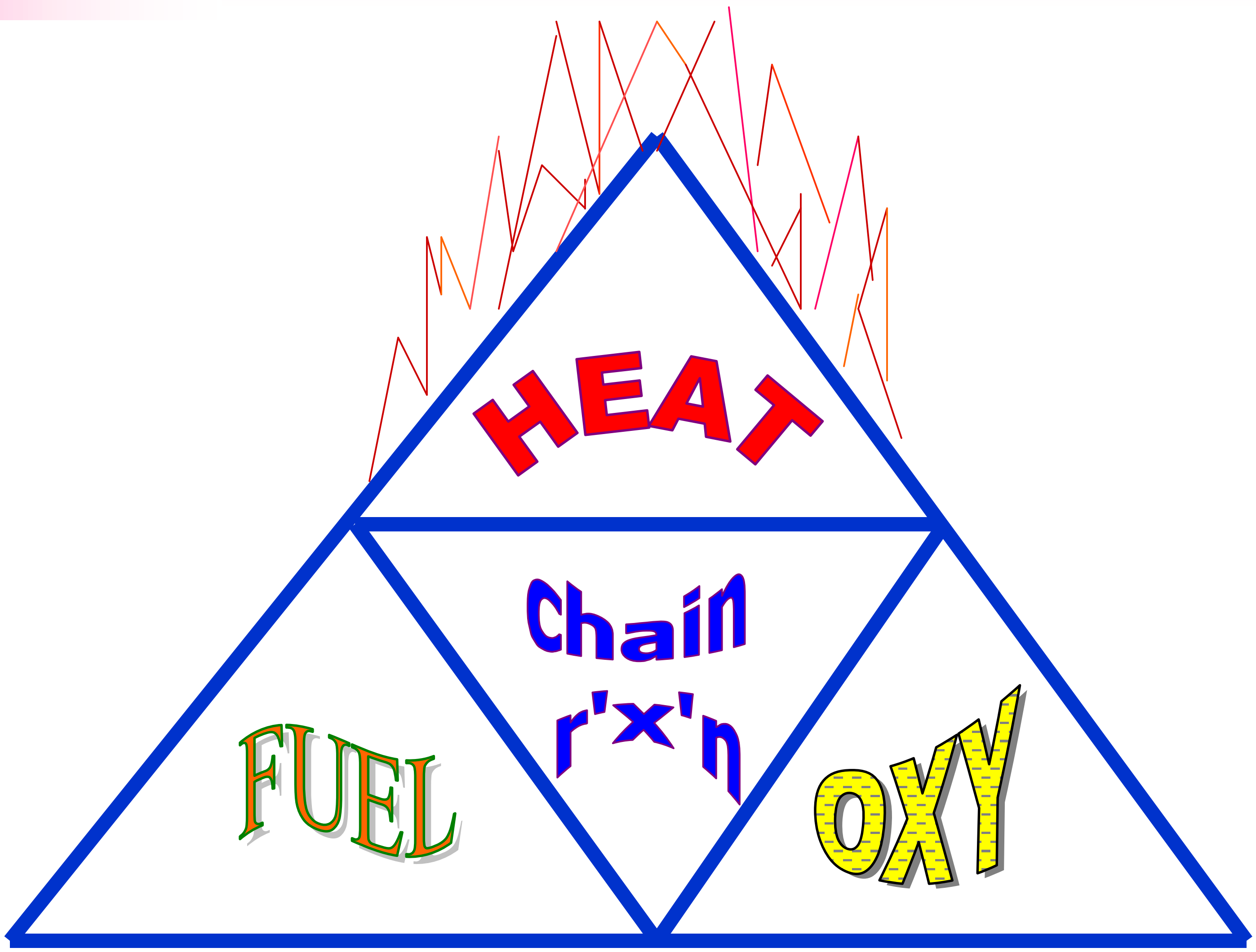
flammable gas

- An ignitable compressed gas; which is

  a) ignitable when in a mixture of 13% or less by volume in air...

  b) has a flammable range of at least 12%...

Let's look at some properties of ignitable gases!!!


HEAT
Chain
r'x'n
FUEL
OXY

What does Air Weigh?

Gases Lighter Than Air

H - Hydrogen

A - Acetylene

H - Helium

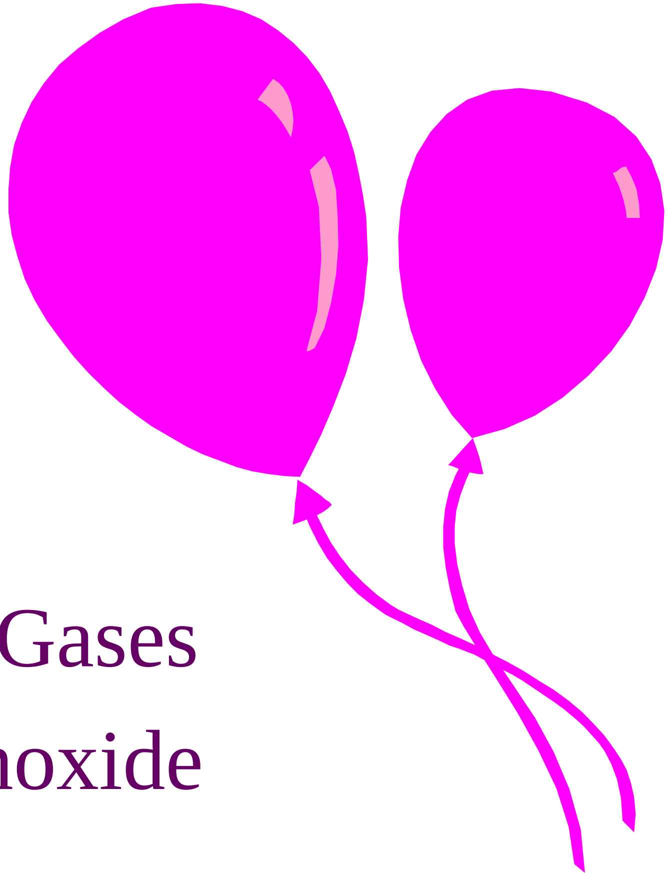
A - Ammonia

M - Methane

I - Illuminating Gases

C - Carbon Monoxide

E - Ethylene



STOICHIOMETRY

1 ____ C_3H_8 + 5 ____ O_2

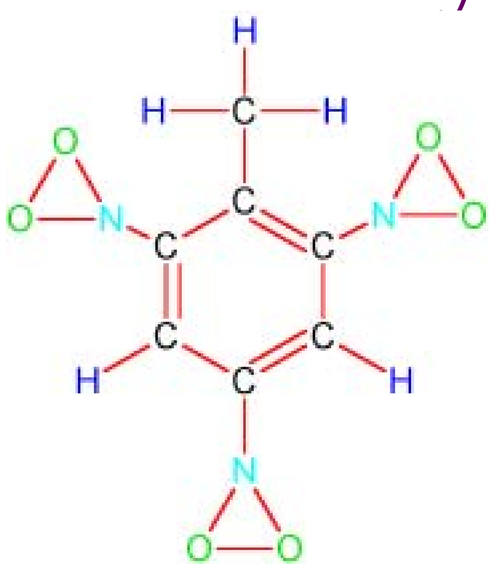
3 → 4

EXPLOSIVES

- Division 1.1 - mass explosion hazard (TNT)
- Division 1.2 - projection hazard but not mass explosion hazard (flares, det. cord)
- Division 1.3 - fire hazard and either minor blast or minor projection hazard (liquid-fueled rocket motors)
- Three other less sensitive types.

EXPLOSIVES

- A substance that is designed to function by explosion, or one which ***by chemical reaction within itself*** is able to function by explosion



Low Explosives

- Function by deflagration

- Deflagration
  - low reaction rate, slower than the speed of sound
  - very rapid autocombustion from the surface inward
  - initiation by contact of a spark or flame, but may be by impact or friction
  - examples: black powder, smokeless powder

Blasting Agents

- Most common agent is a fuel-oxidizer system:

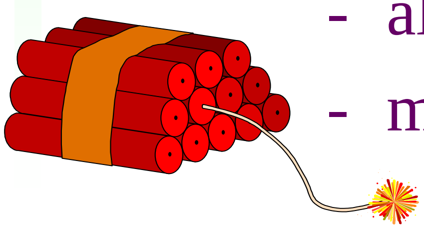
ammonium nitrate and fuel oil

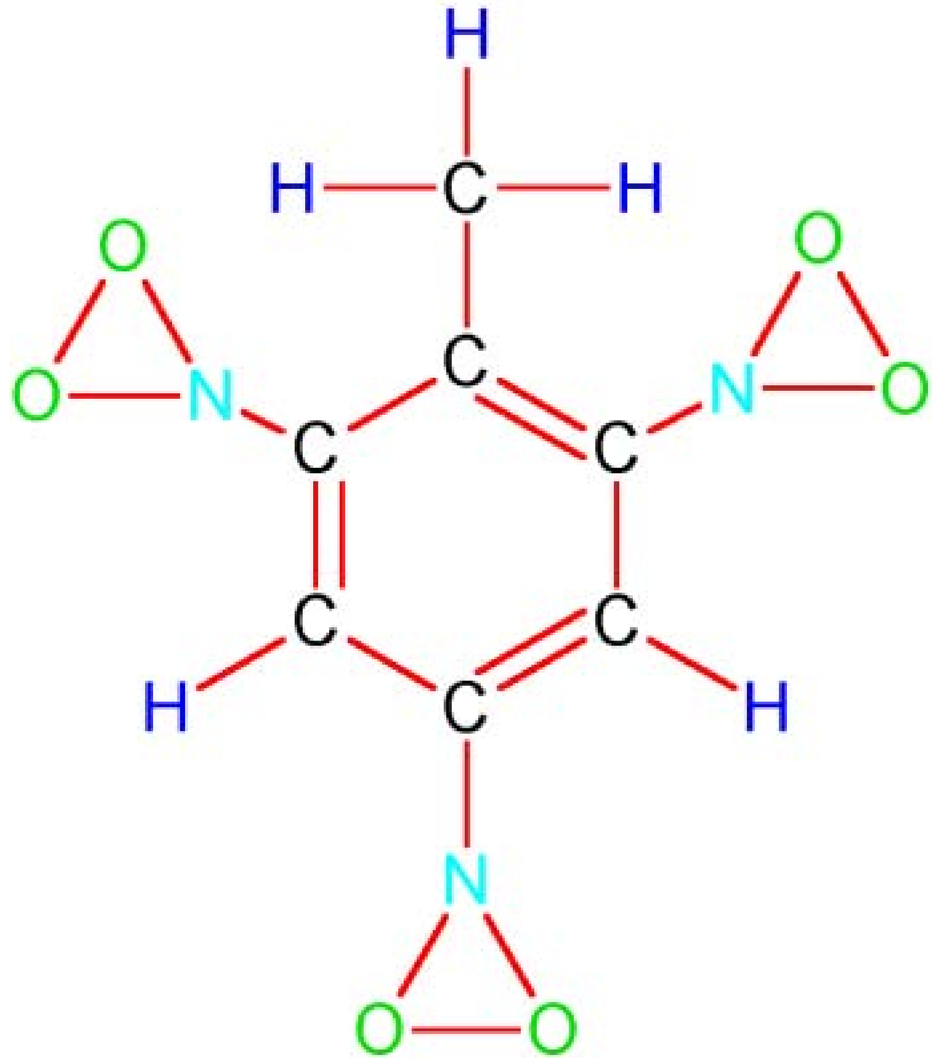
a.k.a. ANFO.

- Not considered a high explosive, but can detonate under fire conditions.

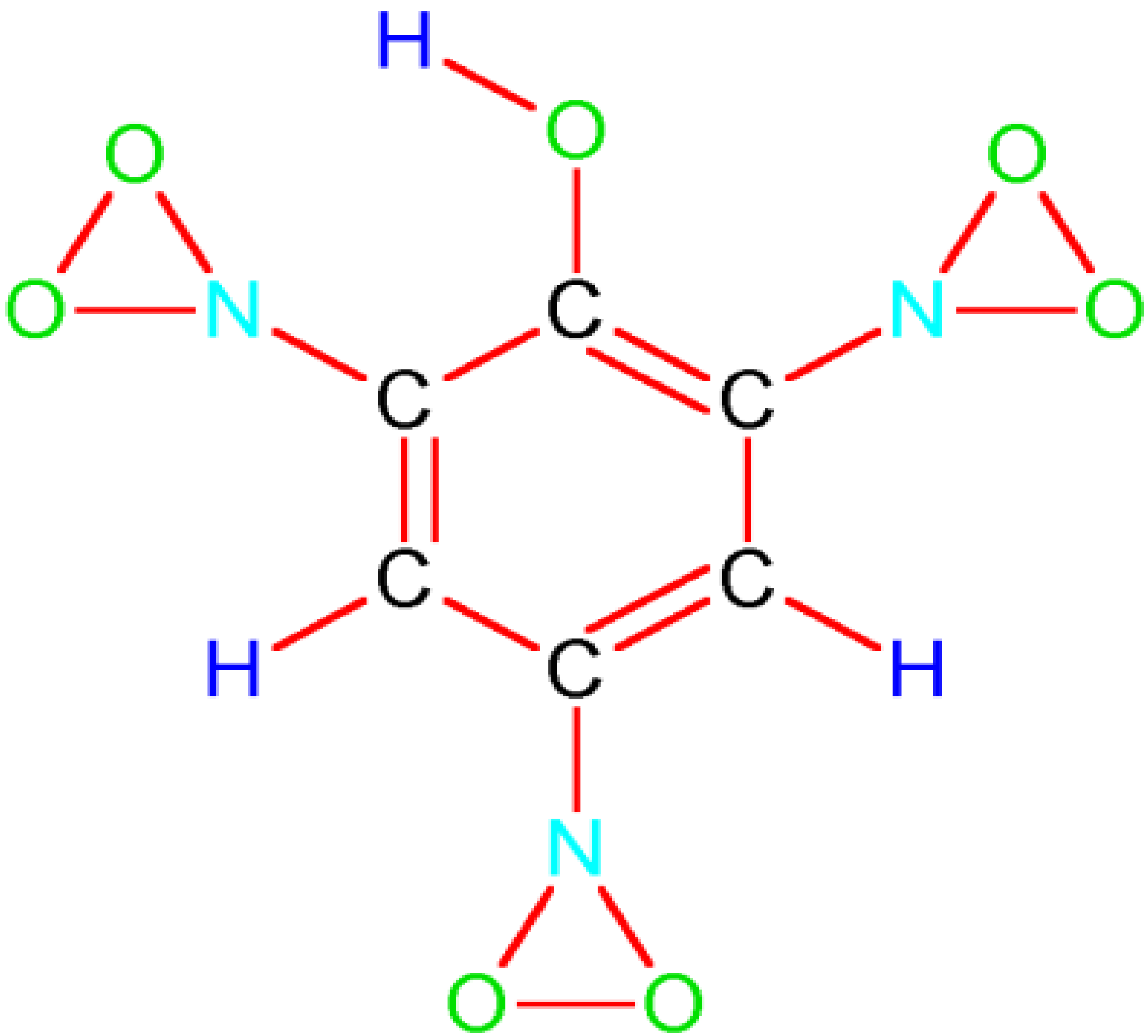
High Explosives

- Function by detonation
- Detonation
  - high reaction rate - faster than the speed of sound
  - almost instant decomposition of a high explosive
  - may be initiated by mechanical impact, friction or heat
  - accompanied by high pressure and temperature waves





trinitrotoluene



Picric Acid